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ABSTRACT

In this paper we report some results of the analysis of released items of the Third International Mathematics and Science Study (TIMSS). This analysis is part of a research project in process related to Mexican high school curricula from an international perspective and, the mathematics students' performance in this school level. The results obtained up to now are related to the mathematical curriculum content underlying the set of TIMSS assessment items. The findings suggest a great wealth of mathematical contents and some skills and abilities needful of answering to this set of items. However, in this paper we report only the results corresponding to mathematical content, highlighting some detected differences between the Mexican high school curricula and these contents. (Author)

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HIGH SCHOOL CURRICULUM CONTENTS FROM AN INTERNATIONAL PERSPECTIVE

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Abstract: In this paper we report some results of the analysis of released items of the Third International Mathematics and Science Study (TIMSS). This analysis is part of a research project in process related to Mexican high school curricula from an international perspective and, the mathematics students' performance in this school level. The results obtained up to now are related to the mathematical curriculum content underlying the set of TIMSS assessment items. The findings suggest a great wealth of mathematical contents and some skills and abilities needful of answering to this set of items. However, in this paper we report only the results corresponding to mathematical content, highlighting some detected differences between the Mexican high school curricula and these contents.

Introduction

The need to know how young people are being prepared at school leads us to the evaluation of student performance as well as instruction, curricula and teacher practices. The Third International Mathematics and Science Study (TIMSS), conducted in 1992-1995, and its repetition (TIMSS-R), in 1999, was the most extensive and ambitious international mathematics and science evaluation of comparative education achievement ever undertaken (Michel, & Kelly, 1996; Gonzales et al., 2000). The main goal was to examine student achievement in some school grade levels to try to understand the nature and extent of student achievement and the context in which it occurs (Michel & Kelly, 1996).

For TIMSS implementation, analysis and data collection, different instruments were prepared. They included questionnaires and interviews for students, teachers and principals of their schools, videotapes, classroom activities and case studies of three countries, curriculum analyses of participant countries, and assessment item sets for students (Mullis & Michel, 1996).

One of the most important tasks carried out by TIMSS was the design and selection of the item sets in such a way that this would reflect the knowledge and some skills and abilities that students should acquire and develop according to their age and school grade level. For this purpose, the TIMSS team took into account the analysis of curriculum guides, textbooks and other material that allowed them to determine the common characteristics of most of the participant countries.

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In this paper we report some results of a research project in process related to Mexican high school mathematics curricula from the international perspective, implicitly suggested by the TIMSS assessment instruments. This research project began with the analysis of the TIMSS instruments from different perspectives:

- Determining the underlying content in the set of items to identify a curriculum, which we can refer to as international, at the content level. This international curriculum can serve as a reference for the curriculum reform in Mexican high school mathematics education, since it will allow us to compare the Mexican mathematics curriculum with this broad opinion of specialists in both mathematics and mathematics education world-wide.
- Identifying particular skills and abilities, procedures and solution strategies for each item. Doing this we can have a broad picture of the things that can be assessed with this set of items. This information allows us to have a richer curriculum that includes not only content knowledge but also processes, abilities and skills.
- Designing instruments complementary to those of TIMSS to identify more clearly the knowledge, skills and abilities that students should develop and acquire. The enrichment of these items by means of adaptation and incorporation of new ones, will allow us to investigate more deeply into the knowledge, skills, and abilities identified in the original instruments, seeking to have a more profound diagnostic of Mexican high school mathematics education.

Under the assumption that the TIMSS set of items reflects a desirable curriculum for high school systems from an international perspective, we intended to determine the common contents and differences between the Mexican high school and this international curriculum. We suppose that Mexican high school curriculum contents cannot be very different from the one outlined by this international perspective, since it is not isolated from international expectations, mainly due to the current global tendency in which we are immersed.

Assessment of Knowledge, Skills and Abilities

One fundamental stage in the design and analysis of items to assess student performance is to know accurately what it is to be assessed. To be clear in this aspect, it is desirable to distinguish between knowledge, skills and abilities.

Knowledge acquisition is a process that involves both the memorization of facts, principles and laws and the appropriation of mathematical concepts (Haladyna, 1997). Although the purposes and goals of mathematics education in most of the Mexican educational systems are guided to promote the development of competencies and skills (SEP, 1999), the assessment has been focused mainly on content knowledge. In many countries, however, there is a growing interest in the way that we are assessing student performance. For example, *The Principles and Standards for School Math-*

ematics suggests that assessment "should focus on students' understanding as well as their procedural skills" (NCTM, 2000, p. 23).

Skills and abilities are cognitive processes that can be inferred by means of studying the students' behavior when they are carrying out a certain activity. Skills are specific actions that are characteristic of the activity, while abilities are the psychological characteristics of that person who carries out the activity (Krutetskii, 1976). These aspects have been attended to little in the assessment process, not because they are seen as less important, but because of the difficulty in studying them. It is important to mention, however, that currently this is a central part of some mathematics education research. It seems to be that a qualitative inquiry methodology applied to the assessment process is an appropriate way to investigate these issues (Romberg & Collins, 2000).

Knowledge, skills and abilities are not acquired and developed in an isolated way, they interact and develop in a combined form (Strenberg, 1999).

Taking into account these aspects, our analysis is focused on the identification of the mathematical contents reflected by the TIMSS items, which in turn give us a well-rounded picture of the knowledge involved.

Methods and Procedures

From the TIMSS perspective, curriculum was considered to have three manifestations:

- The intended curriculum, that is, the mathematics that one expects students to study and learn in school;
- The implemented curriculum refers to what the teacher actually teaches, in terms of their own interpretation of the intended curriculum; and,
- The attained curriculum, which refers to what the students are really learning (Michel & Kelly, 1996).

These manifestations tell us that official intentions can be different from what the students are really learning. Determining the underlying contents in the TIMSS items leads us to identify one part of a deliberate international curriculum that may not correspond to what the students are really achieving; this international curriculum, however, integrates the expectations for students at an international level.

The attained curriculum can be determined by assessing student achievement in those expectations marked by the intended curriculum. As we have mentioned, one of the purposes in determining the underlying curriculum in the TIMSS item set is to have a broad picture of the knowledge, skills and abilities that we can assess with this pool of items. Their implementation will allow us to have a diagnostic of the actual situation of the Mexican high school system, and a framework with which to compare expectations and students' performances in those contents that are common in both the Mexican and the international curricula.

In 1996-98 in Mexico a team of mathematics education researchers and mathematics researchers, conducted the study "*Propósitos y Contenidos de la Enseñanza de las Matemáticas en el Nivel Medio Superior en México*" (Rivera et al., 2000), which was focused on the intended curriculum across the country. This study shows the complexity and diversity of Mexican high school systems; it also highlights some schools systems that are representative of them.

For our analysis, we used the results of this study and the 57 released TIMSS mathematics items that correspond to the high school system in Mexico. The data gathered by this means is appropriate for a qualitative approach; so we used this method of inquiry.

Results

TIMSS classified the items in various ways. One of them is by the format, multiple choice and open-ended (short and extended response) items.

The use of multiple-choice items has some advantages, for example, the ease in assigning and applying scores, mainly when we want to test a large population. The main purpose to using them in assessing student performance is to determine the knowledge acquired as a product of the learn process (Haladyna, 1997). This kind of format, however, is not appropriate for assessing some skills and abilities, since these are aspects that can only be evaluated by analyzing the solution process of a problem or the students' behavior when facing an activity. Others that, besides measuring the students' knowledge base, also try to develop certain competencies are beginning to substitute multiple choice items, which is in widespread use in standardized tests. Examples of this are the performance assessment packages that consist of combined-solving problems and/or open-ended problems.

The item format gives us insight into the extent of the answer that students should give us, and this extent reflects the depth of the assessment process, so this is an aspect that we take into account in the analysis.

TIMSS classified the items in the Final Year of Secondary School test (final year of high school in Mexico) into mathematics literacy and advanced mathematics item sets. The former was to be applied to a sample of all students in the last year of secondary school, while the advanced mathematics test was to be applied to students who were taking advanced mathematics courses in their final year of secondary school. The items in the latter were classified in turn as numbers, equations and functions, geometry, calculus, probability and statistics, and validation and structure.

Although the mathematics literacy items were not explicitly classified in more detail, our analysis suggest the following more relevant contents:

- *Numbers and number sense*: Whole numbers and rational numbers, rational numbers representations in decimal and fractional forms and their relationships, basic operations with whole numbers and rational numbers, basic operation

properties, unit conversion, reasonableness of results, order of magnitude, estimation, rounding, number patterns, and various types of percent problems.

- *Proportionality*: Direct and inverse proportionality, ratio, and scales in graphs.
- *Probability and statistics*: Data representation; interpreting graphs, plots and charts, prediction and inference from graphs and charts, notions of sample and population, randomness, measures of central tendency (mean), fitting lines, numerical probability; notions of mathematical expectation, use of notation and vocabulary.
- *Variables and functions*: Dependence between variables, function graphs, interpreting graphs of functions, relationship between graphs and equations, recall and use of formulas, mean rate of change, and increments.
- *Geometry*: Longitude, area and volume measurements, graphic estimation, and recall of names of basic figures (triangle, square, rectangle, hexagon, cube).

For the advanced mathematics items, we identified the content knowledge in each one of the TIMSS categories:

- *Numbers, equations and functions*: Real and complex numbers, basic operations with these numbers, conjugation of complex numbers, operational properties, exponents and radicals (square root), prime factors, permutations and combinations, direct and inverse relationships between variables, variation range, approximation, estimation, rounding, precision, inequalities, posing and solving equations with real and complex numbers, linear systems of equations, rearranging formulas, equations of conic curves and equations of planes, logarithmic exponential and trigonometric functions, use of specialized notation and vocabulary.
- *Calculus*: Routine computation of limits with radicals (square root), the derivative and the integral (in speed and acceleration context, and their relationship), the derivative as a function (graphic representation and their relationship with the function), graphic representation of the integral as a primitive function, graphic representation of the integral as the area of a region, exponential and logarithmic functions and their relationship, trigonometric function and the use of some trigonometric formulas in problem solving situations, series (geometric and arithmetic), and the use of a more specialized vocabulary and notation. (We also distinguished some algebraic processes, like the conjugated product of binomials, and basic algebraic operations).
- *Geometry*: Representation of points on a plane, the distance between two points on the plane, longitude, area and volume measurement and units, properties of triangles (exterior and interior angles, the sum of interior angles, inscribed

right triangles in the circumference, congruency and similarity), parallelism and perpendicularity, regular polygons (their area), conic sections (identification of equations and graphics), Pythagorean theorem applications, lines and planes in space, graphic estimation of an area, spatial visualization, coordinate systems in two and tree dimensions, translation, reflection, rotation, invariance, vectors, vector representations on a plane, angle between vectors, sum, difference and product by scale operations with vectors, and correct use of a more specialized notation.

- *Probability and statistics*: Data representation and analysis, interpreting graphs, plots and charts, process of randomness, measures of central tendency, counting principles, scales, estimation, prediction and inference, classic probability, conditional probability, numerical probability; fitting lines, correlation, and specialized vocabulary.
- *Validation and structure*: There is only one item in this category related to formal logic.

The mathematics literacy items and the advanced mathematics items differ considerably in quantity, context, notation and vocabulary and content knowledge. For instance, the items related to geometry in the literacy mathematics test are fewer, and most of them are related to the names of geometric figures and measurement. In the advanced mathematics test, most of them are related to the properties of geometric figures, representations and spatial visualization.

Most of the items in the literacy test are in context; they incorporate situations and activities from daily life, while most of the items in the advanced mathematics test are in a mathematical context, or in a context that may not be very familiar to students; for example, item L3 related to the decomposition of a radioactive element.

The Mexican high school system is complex. There is a diversity of subsystems, both public and private. There are no standards or benchmarks to support the curriculum design and therefore, we found a diversity of curriculum guides. Although all of them include mathematics, some only in one part of the program and others during the whole program.

Within this diversity, however, there exist common mathematical contents, related to algebra, trigonometry and analytical geometry (Rivera et al., 2000). These contents relate well to the international curriculum that we described above (although TIMSS does not refer explicitly to algebra contents, some of them correspond to the algebra courses in Mexico); for example, solution of linear equations, trigonometric functions in problems that involve right triangles or the study of conic sections.

In general terms, our findings show that large differences do not exist between the curriculum contents in Mexican high schools and the international curriculum. There are, however, some differences. For example, numeric and graphic estimation is present in many of the TIMSS items, both in the advanced mathematics test and in the

literacy test, but this notion was not identified in most of the Mexican high school curriculum contents.

Also, we found differences in the treatment of certain concepts. For example, item K5 in the advanced mathematics test refers to the identification of relationships between the function and their first and second derivative in a graphic representation (and some data in analytical representation). There are no instances of this type of treatment in the high school curriculum in Mexico. The derivative concept is present in the calculus courses (In Mexico, the students that take calculus courses, are those who expect to enter to college in areas related to mathematics and science studies or engineering). The treatment of this concept is in terms of the application of formulas to solve routine problems. The graphic representation of the derivative is only used as a way of introducing this concept in an intuitive form, such as for the slope of a tangent straight line to the graph of a function in a point. The second derivative is not present in the Mexican high school curriculum.

Although the content is only one part of the curriculum, it is an important one that allows us to appreciate the wealth of content knowledge and the expectations for students. The framework that TIMSS provides us is an excellent opportunity to reflect on these expectations.

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